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DIRECTIONS

FOR USING THE NEW IMPROVED

HADLEY's QUADRANT.

[+ Sextant]

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Plate I.

fig. 1.

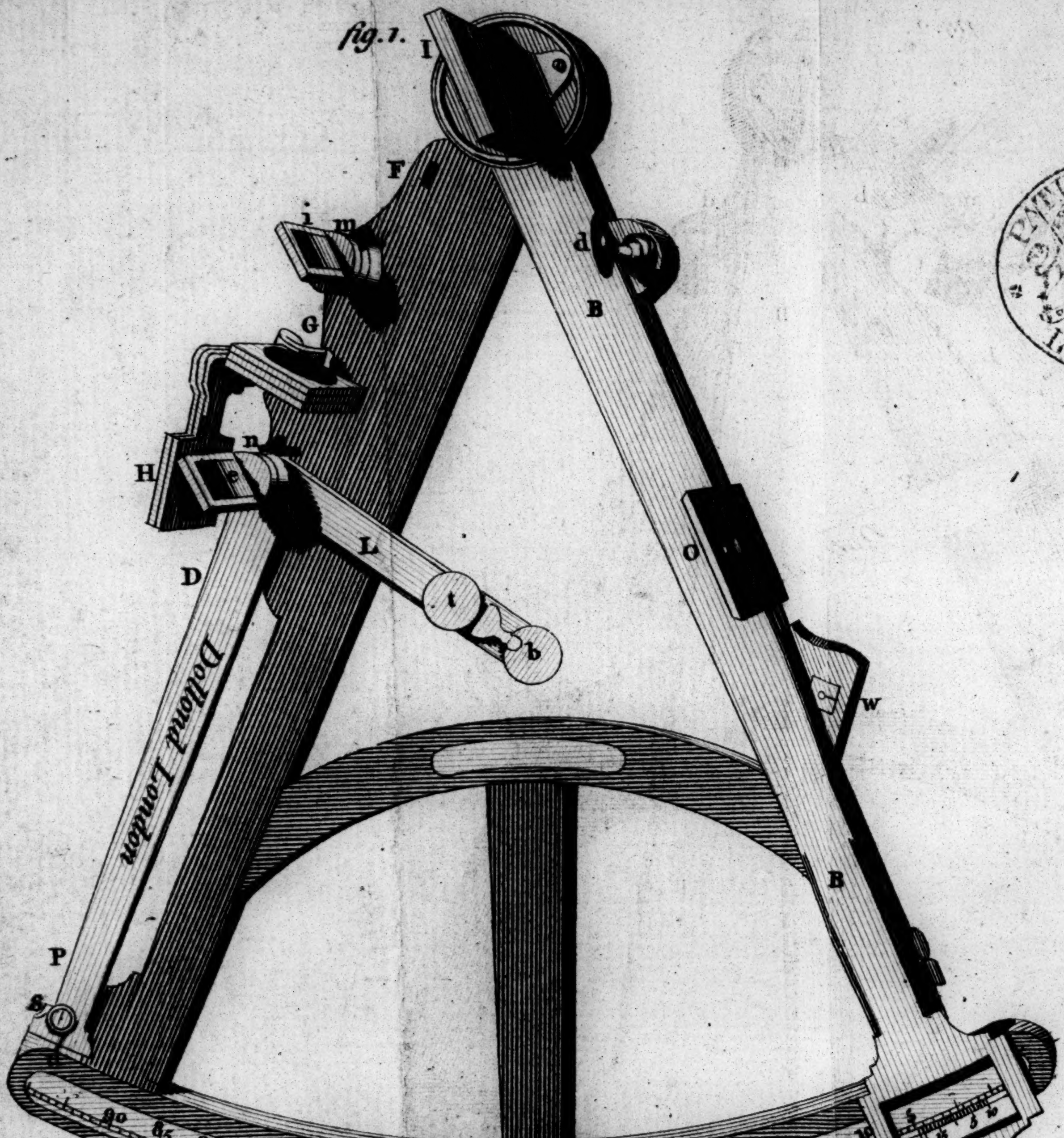

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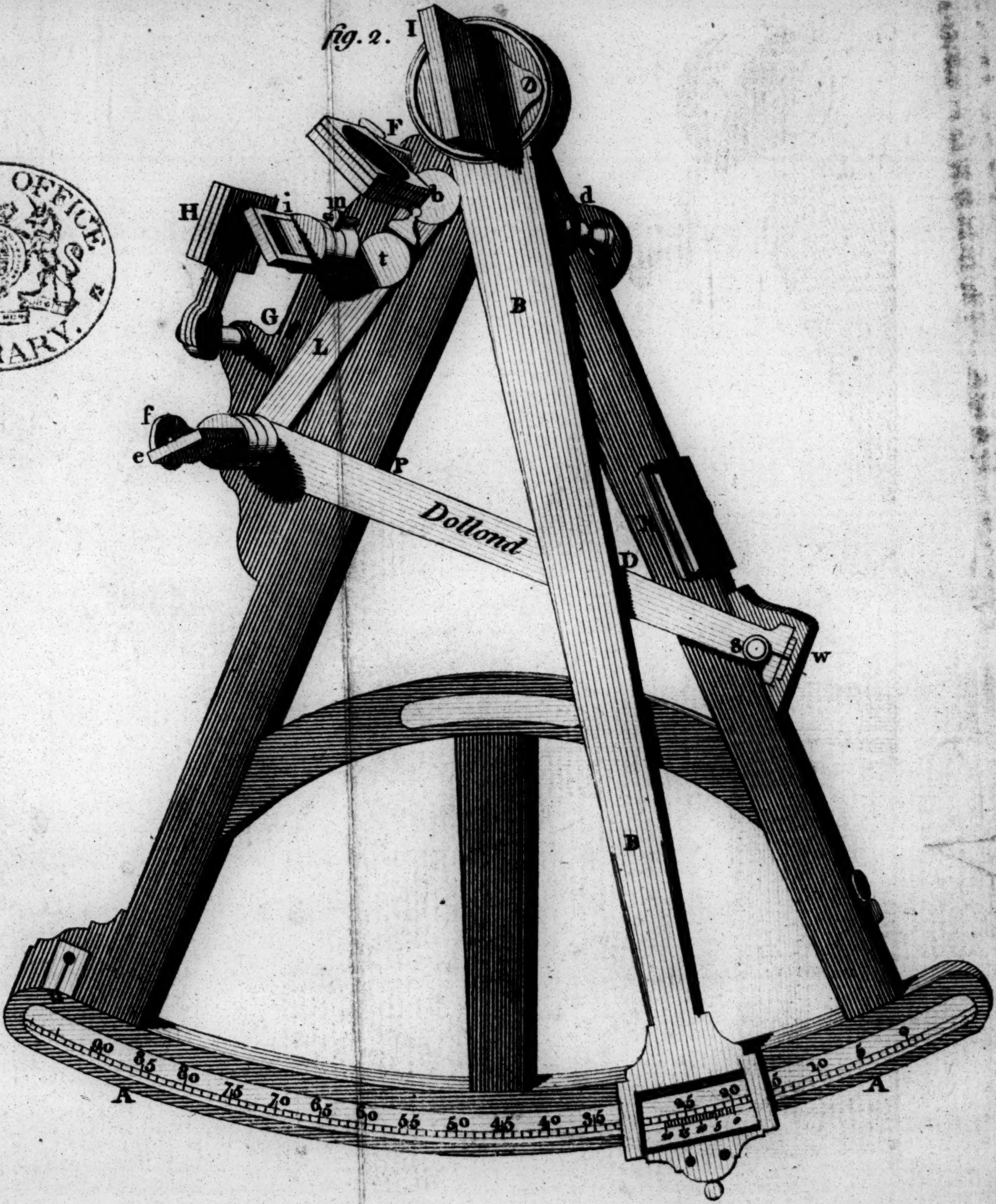
fig. 2.



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DIRECTIONS

FOR USING THE NEW IMPROVED

HADLEY'S QUADRANT;

[and Sextant]

WITH THE NEW METHOD OF

ADJUSTING THE GLASSES

FOR THE

BACK OBSERVATION.

BY HIS MAJESTY'S ROYAL PATENT.

MADE BY

P. AND J. DOLLOND,

OPTICIANS TO HIS MAJESTY,

IN

ST. PAUL'S CHURCH YARD,

LONDON.

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DIRECTIONS

FOR USING THE IMPROVED

HADLEY's QUADRANT, &c.

THE theory of this inſtrument was ſo well underſtood, and the ſeveral ways of placing the glaſſes ſo thoroughly conſidered, by the inventor Mr. Hadley, that very little improvement has, or can be made in that reſpect. But, as the perfection of every inſtrument depends not only on an advantageous diſpoſition of the parts, but on thoſe parts admitting of an eaſy and accurate adjuſtment, here is great room for improvement. For it is a maxim *now* univerſally received among Aſtronomers and practical obſervers, that the parts of no inſtrument can be ſo fixed, as ever to remain in the preciſe poſition they had when firſt put out of the maker's hands. On the contrary, the principal parts muſt be at firſt made moveable, and then their poſition

examined

examined and rectified, from time to time, by the obſerver. If the inſtrument be not provided with the neceſſary means of adjuſtment, the obſervations cannot be accurate; and if the adjuſtment of any of the parts be troubleſome and perplexing, the uſe of ſuch parts will moſt commonly be neglected.

This has been the caſe with Hadley's quadrant, particularly in reſpect to the back obſervation. For the methods hitherto known of adjuſting it at ſea for that obſervation are ſo inaccurate and troubleſome, and require ſuch ſingular circumſtances in the weather, that ſcarce any uſe has been made of that part of the inſtrument.

The improvements now offered to the Public are deſigned to render *all* the adjuſtments of the glaſſes more eaſy and accurate than heretofore, but more particularly thoſe required for making the back obſervation. This very valuable part of the inſtrument, hitherto much neglected, it is hoped, will now come into general uſe. For, by theſe new improvements, the neceſſary adjuſtments may be made at any time when an obſervation is practicable, without waiting for ſuch favourable circumſtances as ſeldom occur; and this may be done with the ſame eaſe, and with the ſame accuracy, as in the fore obſervation. How this is effected will be eaſily underſtood by the deſcription and directions following:

Fig. 1. and 2. repreſent the inſtrument furniſhed with the different apparatus. This inſtrument is an octant, for the arch *AA* contains only 45 degrees, but, becauſe half degrees on the arch (by the nature of reflection) anſwer to whole ones in the angle meaſured, it is therefore divided into 90 degrees, from whence the inſtrument has generally been called a quadrant. Each degree on the arch is again divided into three parts or 20 minutes.

BB is the principal index that turns on the center *c*. The end that moves on the graduated arch *AA* carries the *vernier* diviſions, by which each diviſion on the arch is ſubdivided to every minute. This index carries the largeſt reflecting glaſs *I*, called the index glaſs, which is fixed over the center *c*, in a braſs frame, perpendicular to the plane of the inſtrument.

To prevent the index glaſs from being bent by the ſcrews that faſten it, the upright plane of braſs, againſt which the back of the glaſs lies, has three points; and the braſs frame, that bears againſt the front of the glaſs, has likewiſe three points directly oppoſite to the former. On the back of the frame are three ſcrews anſwering to thoſe points. When thoſe ſcrews are ſcrewed up, the glaſs is then preſſed between theſe points in three places only, and therefore it cannot be diſtorted; for a plane will always conform its poſition to any three points.

* The index glaſs receives the rays from the ſun, or any other object, and reflects them to the leſſer glaſs *i*, called the *fore horizon glaſs*. The part of this glaſs next the plane of the inſtrument is quickſilvered, the other part is tranſparent. This fore horizon glaſs receives the image of the object from the index glaſs, and reflects it to the eye placed at the ſight *d*. The object ſeen by reflection; by turning the index, may be brought to coincide with the object ſeen by direct viſion through the tranſparent part of the glaſs.

For the back obſervation there is another ſuch ſmall glaſs *e* placed on the ſame ſide of the octant as the former, but farther from the center; this is called the *back horizon glaſs*; it receives the image of the object from the index glaſs, and reflects it to the eye placed at the ſight *f*.

In this caſe, the object ſeen by reflection is behind the obſerver, but, by the two reflections from the glaſſes *I* and *e*, it is made to appear directly forward. This object, by turning the index, may be brought to coincide with any object ſeen by direct viſion through the ſight *f*, and through the tranſparent part of the horizon glaſs.

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* This new method of fixing the index glaſs is of great importance. There are few quadrants of the old conſtruction in which the index glaſs is not diſtorted; inſomuch that they give one angle when the obſervation is made by the upper part of the index glaſs, and quite another when it is made by the lower part. A fault much complained of by many eminent aſtronomers and mathematicians, but hitherto not remedied by the inſtrument makers.

There are two red glaſſes, and one green glaſs, ſet in braſs frames, turning on a pin; one of the red glaſſes is lighter, the other darker; ſo that either of them may be uſed ſeparately, or both together as the brightneſs of the ſun may require: the green glaſs may be uſed with the others, or alone if the ſun be very faint; it is alſo of uſe for taking the altitude of the moon, or for taking her diſtance from a ſtar.

When theſe glaſſes are uſed for the fore obſervation, they are fixed at *F*, fig. 2, when uſed for the back obſervation, they are removed to *G*, as in fig. 1.

The ſights *d* and *f* have each of them two holes, to direct the ſight in a line parallel to the plane of the inſtrument; one of theſe holes is juſt the height of the edge of the ſilvered parts of the horizon glaſſes; the other is higher, in order to direct the ſight to the middle of the tranſparent parts of thoſe glaſſes.

The altitude or angle, taken with this inſtrument, is determined by the inclination of the two glaſſes to each other; therefore, when the index is ſet to the beginning of the diviſions on the arch, the fore horizon glaſs *i* ſhould be perfectly parallel to the index glaſs; and the image of the object ſeen by reflection ſhould appear to coincide with the object itſelf ſeen by direct viſion: this is done by adjuſting the horizon glaſs. The accuracy of this adjuſtment depends on the conſtruction of the inſtrument, and the diſtinctneſs of the object made uſe of in the operation. Theſe things having been well conſidered, the following method to be uſed at ſea is propoſed, as being much more exact than any heretofore given.

To adjuſt the fore horizon glaſs at ſea.

TWO adjuſtments belong to the fore horizon glaſs; one to ſet it perpendicular to the plane of the octant, the other to make it parallel to the index glaſs, when the index ſtands at the beginning of the diviſions.

The horizon of the ſea has always been uſed for this adjuſtment, becauſe no method had been thought of to darken the direct rays of the ſun, without darkening the reflected rays at the ſame time; in which caſe the reflected image would always be darker than the object ſeen directly; but by applying ſuch glaſſes behind the horizon glaſſes, as at *H*, the direct rays of the ſun may be weakened more or leſs as its brightneſs may require; the glaſſes being of the ſame ſort as thoſe uſed at *F* and *G*, for darkening the reflected rays. This method of adjuſting by the ſun is much more accurate than by the horizon; the ſun being a bright and diſtinct object, the leaſt error may be ſeen, and the errors in both adjuſtments ſeen at once.

The index being ſet to the beginning of the diviſions, one or more of the darkening glaſſes at *H* being turned behind the horizon glaſs, and the eye placed at the ſight *d*, then hold the inſtrument in a vertical poſition, and direct the ſight to the ſun. If the ſun ſeen by reflection appears on one ſide the ſun ſeen by direct viſion, it ſhews that the horizon glaſs wants adjuſting in the perpendicular poſition: this is to be done by means of the ſcrew *m* that goes through the frame, and is turned by a milled head at the back of the inſtrument. If the ſun ſeen by reflection appears above or below the ſun ſeen by direct viſion, then the error is in the other adjuſtment. This is to be corrected by the lever at the back, that gives the fore horizon glaſs a ſmall motion round its own axis.*

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* This lever is twice the length of thoſe in quadrants of the common conſtruction; it therefore admits of twice the exactneſs in the adjuſtment.

The

By theſe two adjuſtments, the ſun ſeen by reflection may be made ſo perfectly to coincide with the ſun ſeen by direct viſion, as to appear quite ſingle and diſtinct. Thus the glaſſes will be truly adjuſted for the fore obſervation.

The higheſt of the two holes in the ſight ſhould be uſed in making this adjuſtment, that the ſun may be reflected from the tranſparent part of the horizon glaſs, except when his light is very faint; in that caſe the lower of the two holes may be uſed.

To take the altitude of the ſun at ſea by the fore obſervation.

THE ſun is generally bright enough to be ſeen by reflection in the unſilvered part of the horizon glaſs, therefore make uſe of the uppermoſt hole in the ſight *d*; the darkening glaſſes placed at *F*, fig. 2. are to be uſed as the brightneſs of the ſun may require. If the reflection of the ſun's light from the ſea ſhould cauſe the horizon to appear glaring and indiſtinct, then, by turning the green glaſs at *H*, behind the horizon glaſs, this glare will be taken off, and the horizon will appear more diſtinct. Now, holding the octant in a vertical poſition, direct the ſight to that part of the horizon that is under the ſun, and move the index from *o* on the arch, till you ſee the image of the ſun come down nearly to the horizon; then ſwing the octant round a line parallel to the line of ſight: by this means the image of the ſun may be made to deſcribe the arch of a circle whoſe convex ſide is downwards, without ever departing conſiderably from the middle of the tranſparent part of the horizon glaſs. Move the index till the lower edge or limb* of the ſun juſt grazes the horizon, then ſtop the index by the ſcrew at the back, and the degrees and minutes ſhown on the arch will be the *apparent* altitude of the ſun's lower edge above the viſible horizon.

This altitude requires three different corrections before the true altitude of the ſun's center above the real horizon can be obtained.

FIRST CORRECTION. *Add* 16 minutes for the ſun's ſemi-diameter; by this you have the apparent altitude of its center above the viſible horizon.

SECOND CORRECTION. *Subtract* the dip of the horizon (which is occaſioned by the height of the obſerver's eye above the ſurface of the water) according to the following table.

---

* The limb of the ſun or moon ſignifies any part of their apparent circumference which is obſerved; therefore the ſun's lower limb ſignifies the loweſt point of the ſun's circumference, and the ſun's upper limb ſignifies the upper point of the ſun's circumference.

The eye above the ſurface of the ſea in feet.	*Depreſſion, or dip of the viſible horizon, in minutes.*
1	1
4	2
10	3
17	4
27	5
39	6
53	7

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Third Correction. This is neceſſary on account of the refraction of the atmoſphere. For the rays of the ſun, and of all other celeſtial objects, falling obliquely on the earth's atmoſphere, are more or leſs refracted, according to the degree of obliquity with which they enter; that is, according to the altitude of the object. Hence all celeſtial objects appear higher than they really are. Therefore at the end of this tract there is given *A Table of Refractions*, corrected according to the lateſt obſervations. This table is made for every intire degree of apparent altitude, which is as near as is neceſſary. It ſhews how many minutes and ſeconds are to be *ſubtracted* from the apparent altitude on account of refractions. By theſe three corrections you will obtain the true altitude of the ſun's center above the real horizon.

Example for the fore obſervation.

	deg.	min.
Suppoſe the obſerved altitude to be —	34	10
Firſt correction the ſun's diameter *add* —	0	16
	34	26
Second correction. The dip of the horizon for 27 feet, the ſuppoſed height of the obſerver's eye above the water, *ſubtract*	0	5
	34	21
Third correction. For the refraction *ſubtract*	0	1
Remains the ſun's true altitude —	34	20
To obtain the true zenith diſtance *ſubtract* the true altitude from — —	90	0
Remains the ſun's zenith diſtance —	55	40

To take the altitude of a ſtar by the fore obſervation.

SET the index at *o* on the arch, and holding the plane of the octant vertical, direct the ſight to the ſtar; at the ſame time look for the reflected image of the ſtar in the ſilvered part of the horizon glaſs: move the index a little, which will ſeparate the reflected image from the image ſeen by direct viſion; the former will be eaſily diſtinguiſhed from the latter by its motion, when you ſtir the index. Continue to move the index forward, and at the ſame time follow the reflected image of the ſtar with your eye, directing the ſight lower and lower, and changing the poſition of the octant as the ſtar deſcends, till you have brought it down to the horizon; the index will then ſhew the obſerved altitude of the ſtar. It is neceſſary always to keep ſight of the reflected image of the ſtar that you may not miſtake the image of ſome other ſtar for the image of that whoſe altitude you would take. But if the altitude is known nearly, you may ſet the index at firſt to that altitude and holding the octant vertical, direct the ſight to the part of the horizon juſt under the ſtar, and you will find the reflected image near the horizon. By moving the index a little you may bring it to touch as before.

There are only two corrections to be made to the obſerved altitude of a ſtar; the dip of the horizon and the refraction; for the fixed ſtars have no viſible diameter.

Having given all the neceſſary directions for the management of this inſtrument in the fore obſervation, it remains that we do the ſame for the back obſervation, and particularly that we explain the new method of adjuſting the glaſſes for that obſervation; whereby thoſe difficulties which have hitherto rendered this valuable part of the inſtrument uſeleſs, are now intirely removed.

Before we enter upon this, it may be proper to ſhew briefly the different nature and uſes of what is called the *fore*, and what is called the *back* obſervation.

Now by the fore obſervation we can take any angle from 0 to 90 degrees but not more. By the back obſervation we may take any angle from 90 to 180 degrees, ſo that it extends the *quadrant* to a *ſemicircle*. In the fore obſervation the obſerver turns his face to the ſun, and by moving the index, brings the ſun's image down to that part of the horizon which is directly underneath, and which can never be more than 90 degrees diſtant from the ſun. In the back obſervation, the obſerver turns his back to the ſun; (whence it has its name) and by moving the index the image of the ſun is brought from behind the obſerver through the zenith down to that part of the horizon which is then before him, but which is oppoſite to the ſun, and is therefore always more than 90 degrees diſtant from the ſun, and may be 180 degrees diſtant.

The ſame diviſions and the ſame numbers on the limb, ſerve to expreſs the ſun's altitude in the back obſervation, as in the other; but it is becauſe the ſun's altitude is the *ſupplement* of the angle really obſerved, and not the angle itſelf. For if the angular diſtance of any two objects be required, theſe diviſions muſt be underſtood to expreſs the ſupplement of that angle to a ſemicircle, and not the angle itſelf.

As the back obſervation takes all angles from a quadrant to a ſemicircle, and the numbers ſhewn by the index expreſs the ſupplement to 180 degrees, it is evident that when the index ſtands at the beginning of the diviſions the angle will be 180 degrees; and the object ſeen by reflection will then be oppoſite to that ſeen by direct viſion, or in other words, the inſtrument will be in a right line, joining the two objects, and the horizon glaſs will be exactly at right angles to the index glaſs. This being premiſed, it will be eaſy to underſtand the following directions for adjuſting the glaſſes.

The new method of adjuſting the back obſervation by means of an index applied to the back horizon glaſs.

TWO adjuſtments belong to the *back horizon glaſs*, the ſame as to the fore horizon glaſs; one being to ſet it perpendicular to the plane of the inſtrument, the other to make it at *right angles* to the index glaſs, when the index *B B* is at the beginning of the diviſions.

P D, fig. 1 and 2, is an index that turns on the center, over which the back horizon glaſs is fixed. By moving this index from the poſition ſhewn in fig. 2, to the poſition ſhewn in fig. 1, the back horizon glaſs is brought into a poſition like to that of the fore horizon glaſs, and is to be made parallel to the index glaſs by two adjuſtments, which are of the ſame nature with thoſe for the fore obſervation. In ſetting the index *P D*, for this purpoſe, take care to make the line drawn on the end of that index to coincide exactly with the line *u* drawn on a piece of braſs let into the wooden frame; and then make the index faſt by the ſcrew *s*. Set the index *B B* exactly to the beginning of the diviſions, and take away the ſight *f*, fig. 2. Now turn the darkening glaſſes behind the horizon glaſs at *H*, fig. 1, and move the glaſſes for darkening the reflected image from *F* to *G*.

The octant being thus prepared for the adjuſtment, as is repreſented fig. 1, place the eye at the ſight hole *O*; hold the inſtrument in a vertical poſition, and raiſe it up to ſee the ſun through the tranſparent part of the back horizon glaſs. If the ſun ſeen by reflection appears on one ſide of the ſun ſeen by direct viſion, it ſhews that the horizon glaſs wants adjuſting in the upright or perpendicular poſition, which is done by the ſcrew at *n*, fig. 1, that paſſes through the frame, and is turned by a milled head at the back of the inſtrument; if the ſun ſeen by reflection appears higher or lower than the ſun ſeen by direct viſion, then the error is in the other adjuſtment, and muſt be corrected by the lever *L*. This lever being turned by the button *b*, gives a ſmall motion to the horizon glaſs, in order to adjuſt it parallel to the index glaſs; then by tightening the ſcrew *t*, the lever is made faſt to the braſs arm over which it lies.

By this method the back horizon glaſs being made perfectly parallel to the index glaſs; if the index *P D* be moved exactly a quarter of a circle, or 90 degrees, the horizon glaſs muſt then be at right angles to the index glaſs. To do this, move the index from the line at *u*, fig. 1, to the line at *w*, fig. 2. The diſtance of theſe lines being exactly 90 degrees, and being meaſured with the ſame accuracy as the diviſions on the arch, the adjuſtment of the glaſſes by this method is as much to be depended on, as any angle meaſured by the diviſions on the arch *.

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* As this method of adjuſtment depends upon the diſtance of the lines *u* and *w* being exactly 90 degrees, its accuracy may be examined at land by the old methods, ſome of which are very exact, though not practicable at ſea. If the poſition of the horizon glaſs is found to be right by theſe methods, it ſhews that in removing the index *P D*, from *u* to *w*, both glaſs and index has been turned juſt 90 degrees; that the lines *u* and *w* are exactly 90 degrees diſtant.

The reader will find the old methods of adjuſting the octant at land, in a tract intitled *Directions for the uſe of Hadley's quadrant*, printed for T. Cadell in the Strand.

The glaſſes being thus adjuſted, to prepare for the obſervation, turn the darkening glaſſes out of the way; replace the *ſight f*, and puſh down the ſight hole *o* ſo as to leave the braſs frame open at the upper part as it appears at *x*, fig. 2; then the ſun's altitude may be taken by the following directions to the ſame exactneſs as in the fore obſervation.

To take the altitude of the ſun at ſea by the back obſervation.

HOLDING the inſtrument in a vertical poſition, direct the ſight to the part of the horizon oppoſite to the ſun; move the index gradually from o till you bring the darkened image of the ſun *up* to the horizon, ſo that the apparent lower edge may ſtand upon the horizon. Then keeping the octant ſteady, turn yourſelf round upon your heel; or rather twiſt yourſelf from the right to the left, and back again, ſo as to turn the octant round a vertical axis. Obſerve whether the image of the ſun continually touches the horizon during this motion. If it does, then the plane of the octant is held exactly upright, as it ſhould be. But if in that motion the ſun's image croſſes the horizon, the octant is not held upright, and you muſt ſhift its poſition (at the ſame time ſtirring the index if needful) till you can make the lower limb of the ſun glide along the horizon, juſt touching it all the way.

When the ſun is high, inſtead of the motion before deſcribed you may uſe another. Swing the octant round a line parallel to the line of ſight, as was directed to be done in the fore obſervation. By this means the ſun will ſeem to deſcribe the arch of a circle whoſe convex ſide is downward. Move then the index till the lower limb of the ſun juſt grazes upon the horizon in the loweſt part of that arch, and then read off the degrees and minutes as before.

The nearer the ſight is directed in a line parallel to the plane of the inſtrument, the more exact will the obſervation be. For this reaſon it ſhould be ſo held as to ſee the ſun and horizon through the open part of the braſs frame at *x*, and as near the middle of its breadth as may be.

The altitude being obſerved according to the foregoing directions, three corrections are required before the true altitude of the ſun's center above the real horizon can be obtained. It may be noted that the two firſt of theſe are to be applied contrarywiſe to what they are in the fore obſervation.

FIRST CORRECTION. For the ſun's ſemidiameter 16 minutes is to be *ſubtracted*. Becauſe the obſervation is really made with the upper limb of the ſun, though by being brought from beyond the zenith it appears the loweſt.

SECOND CORRECTION. The dip of the horizon is to be *added*. For the altitude being the complement will be too little by the dip of the horizon.

THIRD CORRECTION. For the refraction, is the ſame as in the fore obſervation; it is to be *ſubtracted*.

Example for the back obſervation.

	deg.	min.
Suppoſe the obſerved altitude —	34	10
For the ſun's ſemi-diameter *ſubtract* —	0	16
	33	54
The dip of the horizon for 27 feet *ſubtract*	0	5
	33	59
The refraction of the atmoſphere *ſubtract*	0	1
Remains the ſun's true altitude —	33	58
To obtain the true zenith diſtance *ſubtract* the true altitude from — —	90	0
The true zenith diſtance — —	56	2

Rules for finding the latitude from the ſun's zenith diſtance and declination at noon given.

THE ſun's declination admits of two denominations; that is, north and ſouth. So likewiſe does the ſun's zenith diſtance, for the ſun comes to the meridian either northward or ſouthward of the zenith. The latitude alſo admits of the ſame variation in its denomination. This being premiſed, the following rules will be eaſily underſtood.

Rule I. If the zenith diſtance and declination are of different denominations, their ſum will give the latitude, whoſe denomination will be the ſame as that of the declination.

Rule II. If the zenith diſtance and declination are both of the ſame denomination, their difference will give the latitude, whoſe denomination will be the ſame with that of the zenith diſtance and declination, if the declination is greater than the zenith diſtance. But if the zenith diſtance is greateſt, the latitude will be of a contrary denomination.

The two following rules ſerve to find the latitude of the place from the altitude and declination at noon given.

Rule III. If the altitude and declination are of different denominations, add 90 degrees to the declination, and from that ſum ſubtract the altitude; the remainder is the latitude, and is of the ſame denomination as the declination.

Rule IV. If the altitude and declination are of a like denomination, add the declination to the altitude, and ſubtract that ſum from 90 degrees; if it be leſs, the remainder will be the latitude, and it will be of a contrary denomination. But if it exceeds 90 degrees, the exceſs will be the latitude, whoſe denomination will be the ſame as that of the altitude and declination.

A TABLE *of* REFRACTIONS *to be ſubtracted from the apparent altitude.*

Alt	Refract.		Alt	Refract.		Alt	Refract.		Alt	Refract.		Alt	Refract.	
d.	min.	ſec.	d.	min.	ſec.	d.	min.	ſec.	d.	min.	ſec.	d.	min.	ſec.
1	24	29	19	2	44	37	1	16	55	0	40	73	0	17
2	18	35	20	2	35	38	1	13	56	0	38	74	0	16
3	14	36	21	2	27	39	1	10	57	0	37	75	0	15
4	11	51	22	2	20	40	1	8	58	0	35	76	0	14
5	9	54	23	2	14	41	1	5	59	0	34	77	0	13
6	8	28	24	2	7	42	1	3	60	0	33	78	0	12
7	7	20	25	2	2	43	1	1	61	0	32	79	0	11
8	6	29	26	1	56	44	0	59	62	0	30	80	0	10
9	5	48	27	1	51	45	0	57	63	0	29	81	0	9
10	5	15	28	1	47	46	0	55	64	0	28	82	0	8
11	4	47	29	1	42	47	0	53	65	0	26	83	0	7
12	4	23	30	1	38	48	0	51	66	0	25	84	0	6
13	4	3	31	1	35	49	0	49	67	0	24	85	0	5
14	3	45	32	1	31	50	0	48	68	0	23	86	0	4
15	3	30	33	1	28	51	0	46	69	0	22	87	0	3
16	3	17	34	1	24	52	0	44	70	0	21	88	0	2
17	3	4	35	1	21	53	0	43	71	0	19	89	0	1
18	2	54	36	1	18	54	0	41	72	0	18	90	0	0

A TABLE *of the Sun's Declination, for the* FIRST *Year after* LEAP *Year.*

	S.		S.		S.		N.		N.		N.		N.		N.		N.		S.		S.		S.	
Days	Jan.		Feb.		Mar.		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.
1	23	00	16	54	7	24	4	43	15	13	22	8	23	8	17	59	8	10	3	20	14	36	21	55
2	22	54	16	41	7	1	5	6	15	31	22	16	23	4	17	44	7	49	3	44	14	55	22	4
3	22	48	16	23	6	38	5	29	15	48	22	23	22	59	17	28	7	27	4	7	15	14	22	13
4	22	42	16	5	6	15	5	52	16	5	22	30	22	54	17	12	7	5	4	30	15	33	22	21
5	22	35	15	46	5	52	6	15	16	23	22	37	22	48	16	56	6	42	4	54	15	51	22	29
6	22	28	15	28	5	29	6	37	16	40	22	43	22	42	16	39	6	20	5	17	16	9	22	36
7	22	20	15	10	5	6	7	0	16	56	22	49	22	36	16	22	5	57	5	40	16	27	22	43
8	22	12	14	51	4	42	7	22	17	13	22	55	22	29	16	5	5	35	6	3	16	44	22	49
9	22	4	14	31	4	19	7	45	17	29	23	0	22	22	15	48	5	12	6	26	17	1	22	55
10	21	55	14	12	3	55	8	7	17	44	23	5	22	15	15	31	4	49	6	48	17	18	23	0
11	21	45	13	52	3	32	8	29	18	0	23	9	22	7	15	13	4	26	7	11	17	35	23	5
12	21	35	13	32	3	8	8	51	18	15	23	13	21	58	14	55	4	3	7	34	17	51	23	10
13	21	25	13	12	2	44	9	13	18	30	23	16	21	50	14	36	3	40	7	56	18	7	23	14
14	21	14	12	51	2	21	9	34	18	44	23	19	21	41	14	18	3	17	8	19	18	23	23	17
15	21	3	12	31	1	57	9	55	18	59	23	22	21	31	13	59	2	54	8	41	18	38	23	20
16	20	52	12	11	1	33	10	17	19	13	23	24	21	22	13	40	2	31	9	3	18	53	23	23
17	20	40	11	50	1	10	10	38	19	26	23	26	21	11	13	21	2	7	9	25	19	8	23	25
18	20	28	11	28	0	46	10	59	19	39	23	27	21	1	13	2	1	44	9	47	19	23	23	27
19	20	15	11	6	0	22	11	20	19	52	23	28	20	50	12	42	1	21	10	9	19	37	23	28
					N																			
20	20	2	10	45	0	1	11	40	20	5	23	29	20	38	12	22	0	57	10	31	19	50	23	29
21	19	49	10	23	0	25	12	1	20	17	23	29	20	27	12	2	0	34	10	52	20	4	23	29
22	19	35	10	1	0	49	12	21	20	29	23	29	20	15	11	42	0	11	11	13	20	17	23	29
																	S							
23	19	21	9	39	1	12	12	41	20	41	23	28	20	3	11	22	0	13	11	34	20	29	23	28
24	19	6	9	17	1	36	13	1	20	52	23	27	19	51	11	1	0	36	11	55	20	41	23	27
25	18	50	8	55	2	0	13	20	21	3	23	26	19	38	10	40	1	0	12	16	20	53	23	25
26	18	36	8	32	2	23	13	39	21	13	23	24	19	25	10	19	1	23	12	37	21	4	23	23
27	18	21	8	10	2	47	13	59	21	23	23	21	19	11	9	58	1	46	12	57	21	15	23	21
28	18	5	7	47	3	10	14	18	21	33	23	19	18	57	9	37	2	10	13	17	21	26	23	18
29	17	49			3	33	14	36	21	42	23	15	18	43	9	16	2	33	13	37	21	36	23	14
30	17	32			3	57	14	55	21	51	23	12	18	29	8	54	2	56	13	57	21	46	23	10
31	17	15			4	20			22	0			18	13	8	32			14	17			23	6

A TABLE

A TABLE *of the Sun's Declination, for the* SECOND *Year after* LEAP *Year.*

	S.	S.	S.	N.	N.	N.	N.	N.	N.	S.	S.	S.
Days	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.
1	23 1	17 3	7 30	4 37	15 8	22 6	23 8	18 2	8 15	3 15	14 31	21 54
2	22 55	16 45	7 7	5 0	15 26	22 14	23 4	17 47	7 54	3 38	14 50	22 3
3	22 49	16 27	6 44	5 23	15 44	22 22	22 59	17 31	7 32	4 2	15 9	22 12
4	22 43	16 10	6 21	5 46	16 1	22 29	22 54	17 15	7 10	4 25	15 28	22 20
5	22 37	15 52	5 58	6 9	16 18	22 36	22 49	16 59	6 47	4 48	15 47	22 27
6	22 30	15 33	5 34	6 32	16 35	22 43	22 43	16 43	6 25	5 11	16 5	22 34
7	22 23	15 14	5 10	6 54	16 52	22 49	22 37	16 27	6 2	5 34	16 23	22 41
8	22 15	14 55	4 46	7 17	17 9	22 54	22 30	16 10	5 39	5 57	16 41	22 48
9	22 6	14 36	4 23	7 39	17 25	22 59	22 23	15 53	5 17	6 20	16 58	22 54
10	21 57	14 16	4 0	8 1	17 41	23 4	22 16	15 35	4 54	6 43	17 15	23 0
11	21 48	13 57	3 37	8 23	17 56	23 8	22 8	15 17	4 32	7 5	17 32	23 5
12	21 38	13 37	3 14	8 45	18 11	23 12	22 0	14 59	4 9	7 28	17 48	23 10
13	21 28	13 17	2 50	9 7	18 26	23 15	21 52	14 41	3 46	7 50	18 4	23 14
14	21 17	12 57	2 26	9 29	18 41	23 18	21 43	14 23	3 23	8 13	18 20	23 17
15	21 6	12 36	2 3	9 50	18 56	23 21	21 34	14 4	3 0	8 35	18 35	23 20
16	20 55	12 15	1 40	10 11	19 10	23 23	21 24	13 45	2 37	8 57	18 50	23 23
17	20 43	11 54	1 16	10 32	19 24	23 25	21 14	13 26	2 14	9 19	19 5	23 25
18	20 31	11 33	0 52	10 53	19 37	23 27	21 4	13 7	1 50	9 41	19 19	23 27
19	20 18	11 11	0 28	11 14	19 50	23 28	20 53	12 47	1 27	10 3	19 33	23 28
20	20 5	10 49	0 5	11 35	20 2	23 29	20 42	12 27	1 3	10 25	19 47	23 29
			N									
21	19 52	10 28	0 19	11 55	20 14	23 29	20 30	12 7	0 39	10 47	20 0	23 29
22	19 38	10 7	0 43	12 15	20 26	23 29	20 18	11 47	0 16	11 8	20 13	23 29
									S			
23	19 24	9 45	1 6	12 35	20 38	23 28	20 6	11 27	0 8	11 29	20 26	23 28
24	19 10	9 23	1 30	12 55	20 50	23 27	19 54	11 6	0 31	11 50	20 38	23 27
25	18 55	9 0	1 53	13 15	21 1	23 26	19 41	10 45	0 54	12 11	20 50	23 26
26	18 40	8 38	2 17	13 34	21 11	23 24	19 28	18 24	1 17	12 32	21 2	23 24
27	18 25	8 15	2 40	13 53	21 21	23 21	19 15	18 3	1 40	12 52	21 13	23 21
28	18 9	7 53	3 4	14 12	21 31	23 18	19 1	9 42	2 4	13 12	21 24	23 18
29	17 53		3 27	14 31	21 40	23 15	18 47	9 20	2 28	13 32	21 34	23 15
30	17 37		3 51	14 50	21 49	23 12	18 33	8 58	2 52	13 52	21 44	23 11
31	17 10		4 14		21 58		18 18	8 36		14 12		23 7

A TABLE

A TABLE *of the Sun's Declination, for the* THIRD *Year after* LEAP *Year.*

Days	S.		S.		S.		N.		N.		N.		N.		N.		N.		S.		S.		S.	
	Jan.		Feb.		Mar.		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.
1	23	2	17	6	7	36	4	31	15	4	22	4	23	9	18	6	8	22	3	8	14	26	21	52
2	22	57	16	49	7	13	4	54	15	22	22	12	23	5	17	51	8	0	3	32	14	46	22	1
3	22	51	16	31	6	50	5	17	15	40	22	20	23	1	17	35	7	38	3	55	15	5	22	9
4	22	45	16	14	6	27	5	40	15	58	22	27	22	56	17	19	7	16	4	18	15	24	22	17
5	22	39	15	56	6	3	6	3	16	15	22	34	22	50	17	4	6	54	4	41	15	42	22	25
6	22	32	15	38	5	40	6	26	16	32	22	40	22	44	16	48	6	32	5	4	16	0	22	32
7	22	24	15	19	5	17	6	48	16	49	22	46	22	38	16	31	6	9	5	27	16	18	22	39
8	22	16	15	0	4	54	7	10	17	5	22	52	22	32	16	14	5	46	5	50	16	36	22	45
9	22	8	14	41	4	30	7	33	17	21	22	57	22	25	15	57	5	23	6	13	16	54	22	51
10	21	59	14	22	4	7	7	56	17	37	23	2	22	18	15	39	5	0	6	36	17	11	22	57
11	21	50	14	2	3	43	8	18	17	52	23	7	22	10	15	21	4	38	6	59	17	28	23	2
12	21	40	13	42	3	20	8	40	18	7	23	11	22	2	15	3	4	15	7	22	17	44	23	7
13	21	30	13	22	2	56	9	2	18	22	23	14	21	54	14	45	3	52	7	44	18	0	23	11
14	21	20	13	2	2	32	9	23	18	37	23	18	21	45	14	27	3	29	8	7	18	16	23	15
15	21	9	12	42	2	8	9	45	18	52	23	21	21	35	14	9	3	6	8	30	18	32	22	18
16	20	58	12	21	1	45	10	7	19	6	23	23	21	26	13	50	2	43	8	52	18	47	23	21
17	20	46	12	0	1	21	10	28	19	20	23	25	21	16	13	31	2	19	9	14	19	1	23	24
18	20	34	11	39	0	57	10	49	19	34	23	27	21	5	13	11	1	56	9	36	19	16	23	26
19	20	21	11	18	0	34	11	10	19	47	23	28	20	54	12	51	1	33	9	58	19	30	23	27
20	20	9	10	56	0	10	11	30	20	0	23	29	20	43	12	32	1	9	10	20	19	44	23	28
					N																			
21	19	56	10	34	0	14	11	50	20	12	23	29	20	32	12	12	0	45	10	42	19	57	23	29
22	19	42	10	12	0	37	12	10	20	24	23	29	20	21	11	52	0	22	11	4	20	10	23	29
																	S							
23	19	28	9	50	1	1	12	30	20	36	23	28	20	10	11	32	0	1	11	25	20	23	23	28
24	19	14	9	28	1	2	12	50	20	47	23	28	19	58	11	12	0	25	11	45	20	35	23	27
25	18	59	9	6	1	48	13	10	20	58	23	27	19	45	10	51	0	48	12	5	20	47	23	26
26	18	44	8	44	2	12	13	29	21	9	23	25	19	31	10	30	1	12	12	26	20	59	23	24
27	18	29	8	21	2	35	13	48	21	19	23	23	19	18	10	9	1	35	12	47	21	10	23	22
28	18	13	7	58	2	58	14	7	21	29	23	20	19	4	9	48	1	59	13	7	21	21	23	19
29	17	56			3	22	14	26	21	38	23	17	18	50	9	27	2	22	13	27	21	31	23	16
30	17	40			3	45	14	45	21	47	23	14	18	36	9	4	2	45	13	47	21	42	23	13
31	17	23			4	8			21	56			18	21	8	43			14	7			23	9

A TABLE

A TABLE *of the Sun's Declination, for* LEAP *Year.*

	S.		S.		S.		N.		N.		N.		N.		N.		N.		S.		S.		S.	
Days	Jan.		Feb.		Mar.		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.
1	23	3	17	11	7	18	4	49	15	17	22	10	23	7	17	55	8	5	3	27	14	41	21	58
2	22	58	16	54	6	55	5	12	15	34	22	18	23	3	17	40	7	43	3	50	15	0	22	7
3	22	52	16	36	6	32	5	35	15	52	22	25	22	58	17	24	7	21	4	13	15	19	22	15
4	22	46	16	18	6	9	5	57	16	10	22	32	22	52	17	8	6	59	4	36	15	37	22	23
5	22	40	16	0	5	46	6	20	16	27	22	39	22	47	16	52	6	37	4	59	15	55	22	30
6	22	33	15	42	5	23	6	43	16	44	22	45	22	41	16	35	6	14	5	22	16	13	22	37
7	22	26	15	24	4	59	7	5	17	0	22	51	22	34	16	18	5	52	5	45	16	31	22	44
8	22	18	15	5	4	36	7	27	17	17	22	56	22	27	16	1	5	29	6	8	16	49	22	50
9	22	10	14	46	4	13	7	50	17	33	23	1	22	20	15	44	5	6	6	31	17	6	22	56
10	22	1	14	27	3	49	8	12	17	48	23	6	22	13	15	26	4	44	6	54	17	23	23	1
11	21	52	14	7	3	26	8	34	18	4	23	10	22	5	15	8	4	21	7	17	17	39	23	6
12	21	42	13	47	3	2	8	56	18	19	23	14	21	56	14	51	3	57	7	39	17	55	23	11
13	21	33	13	27	2	38	9	18	18	34	23	17	21	47	14	33	3	34	8	2	18	11	23	15
14	21	23	13	7	2	15	9	39	18	48	23	20	21	38	14	14	3	11	8	24	18	27	23	18
15	21	12	12	46	1	51	10	0	19	2	23	22	21	29	13	55	2	48	8	47	18	42	23	21
16	21	1	12	26	1	28	10	21	19	16	23	24	21	19	13	36	2	25	9	9	18	57	23	23
17	20	49	12	5	1	4	10	42	19	29	23	26	21	9	13	16	2	2	9	31	19	12	23	25
18	20	37	11	43	0	40	11	3	19	42	23	28	20	58	12	57	1	38	9	53	19	26	23	27
19	20	25	11	22	0	16	11	24	19	55	23	28	20	47	12	37	1	15	10	14	19	40	23	28
					N																			
20	20	12	11	1	0	7	11	45	20	8	23	29	20	36	12	17	0	52	10	36	19	54	23	29
21	19	59	10	40	0	31	12	5	20	20	23	29	20	25	11	57	0	29	10	57	20	7	23	29
22	19	45	10	18	0	55	12	26	20	32	23	29	20	13	11	37	0	5	11	19	20	20	23	29
																	S							
23	19	31	9	56	1	18	12	45	20	43	23	28	20	0	11	17	0	19	11	40	20	32	23	28
24	19	17	9	34	1	41	13	5	20	54	23	27	19	48	10	56	0	42	12	1	20	44	23	27
25	19	3	9	12	2	5	13	25	21	5	23	25	19	35	10	35	1	6	12	21	20	56	23	25
26	18	48	8	49	2	29	13	44	21	15	23	23	19	21	10	14	1	29	12	42	21	7	23	22
27	18	32	8	27	2	52	14	3	21	25	23	20	19	8	9	53	1	53	13	2	21	18	23	19
28	18	17	8	4	3	15	14	22	21	35	23	18	18	54	9	32	2	16	13	22	21	29	23	16
29	18	1	7	41	3	39	14	41	21	44	23	15	18	40	9	11	2	39	13	42	21	39	23	13
30	17	45			4	2	14	59	21	53	23	11	18	25	8	49	3	3	14	2	21	48	23	9
31	17	18			4	25			22	2			18	10	8	27			14	22			23	5

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Plate 2.

Fig. 2.

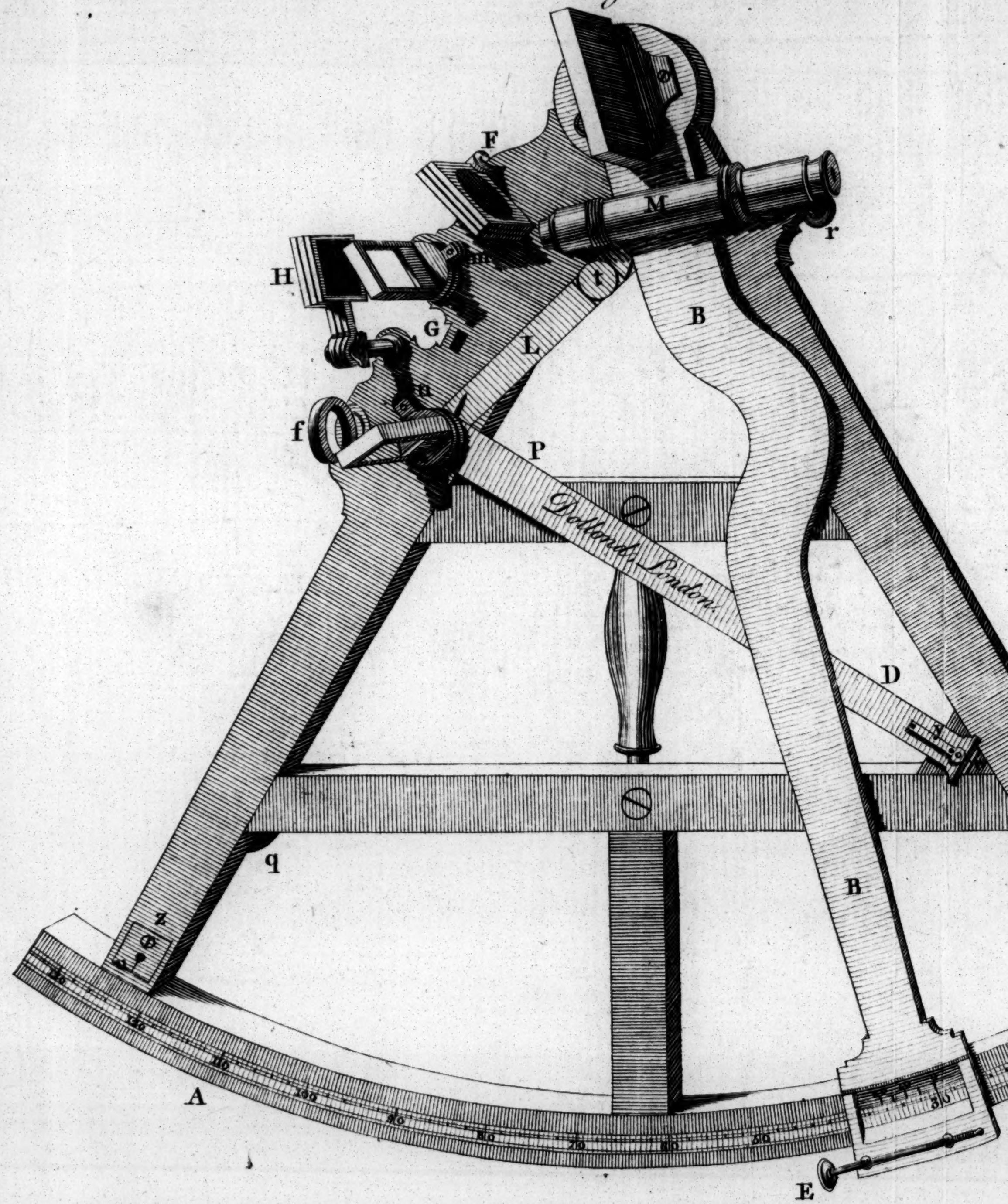

Fig. 3.

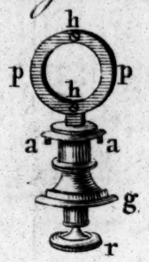

Fig. 1.

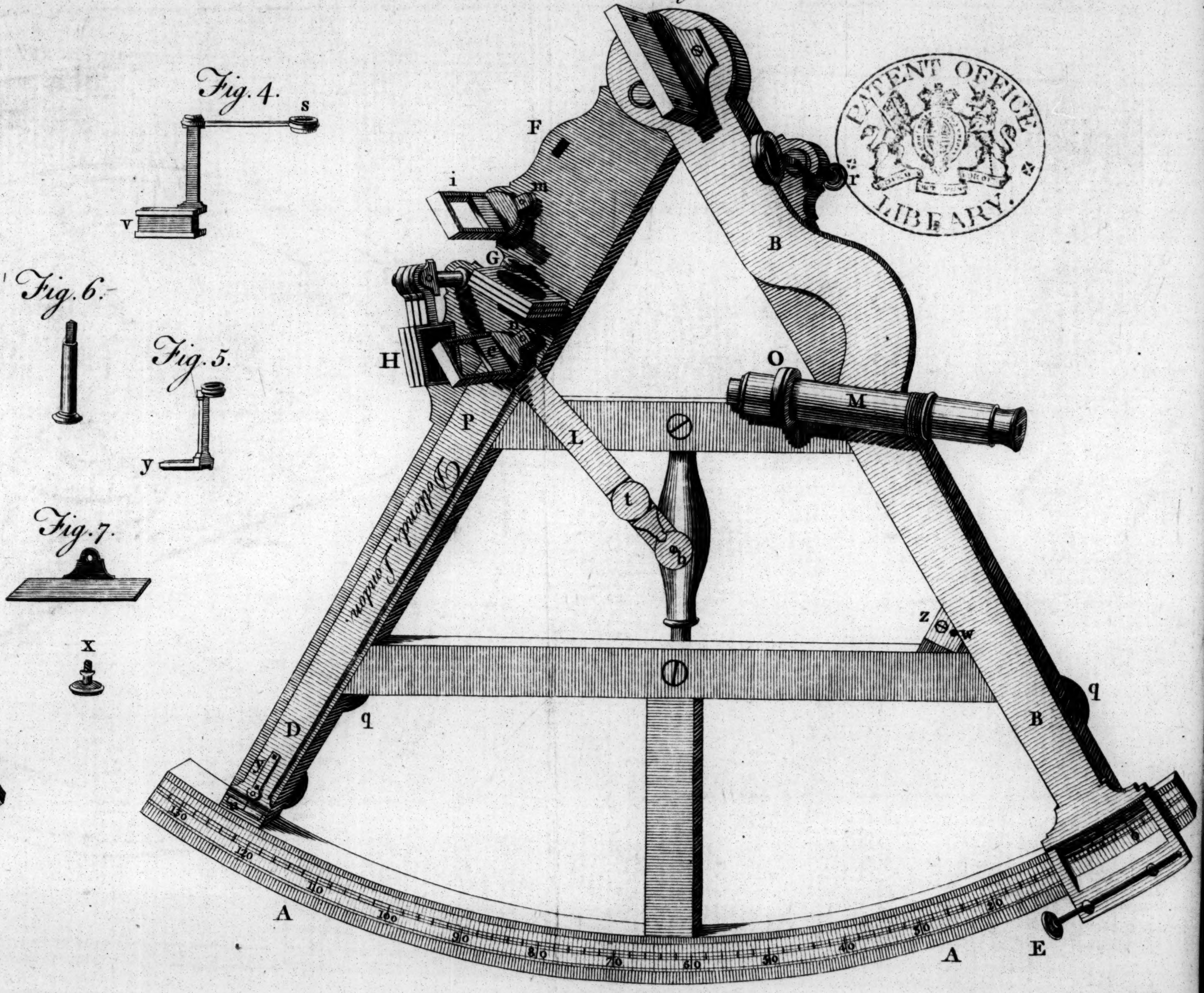

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Fig. 4.

Fig. 6.

Fig. 5.

Fig. 7.

Whitchurch sculp. Barthol

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DIRECTIONS
FOR USING THE
HADLEY's SEXTANT
TO DETERMINE THE
LONGITUDE AT SEA.

THE uſe of this inſtrument in determining the longitude at ſea, is, to obſerve the angular diſtances of the ſun and moon, or the diſtances of the moon from ſome of the principal fixed ſtars. It often happens that the diſtances of the moon from ſuch of the ſtars as are the moſt proper for theſe obſervations exceed 90 degrees, and are ſometimes as great as 120 degrees: for this reaſon it is, that the inſtruments intended for this purpoſe are enlarged to the ſixth part of a circle, that angles may be taken by the fore obſervation *only* as great as 120 degrees; that way of obſerving being more convenient than by the back obſervation. The diſtance of the moon from the ſun (which is preferred to that of the moon from the ſtars by the greateſt aſtronomers) often exceeds 120 degrees, and ſometimes is as great as 180 degrees: theſe great diſtances muſt be taken by the back obſervation; but, as the ſun and moon are two objects that cannot be miſtaken for any other, their diſtances may be taken that way without great difficulty.

As all obſervations for determining the longitude muſt be made with the greateſt exactneſs, the back obſervation, when the glaſſes were adjuſted by the common methods, could by no means be depended on; therefore it has never been thought worth while to furniſh the inſtrument with the apparatus for this purpoſe, and thoſe uſeful obſervations of the ſun and moon above-mentioned have been intirely neglected.

By adjuſting the back obſervation with the moveable index, as deſcribed in the directions for the uſe of the octant, theſe inconveniencies are intirely removed, and the obſervations may be made to 180 degrees with the ſame exactneſs as thoſe with the fore obſervation to 120: beſides this principal advantage, the improved methods of adjuſting the fore obſervation are of great uſe, as the greateſt accuracy is required to determine the longitude by any of theſe methods.

The ſextant, as repreſented in plate 2, is furniſhed with all the parts for adjuſting the glaſſes, as before deſcribed in the uſe of the octant, and alſo ſeveral other parts that are neceſſary to make the obſervations with that accuracy which is required in the uſe of this inſtrument.

The arch *AA* is divided into 120 degrees; each degree is divided into three parts, and by the vernier diviſions it is ſubdivided to every minute.

The principal index *BB*, that carries the vernier diviſions along the arch, may be made faſt to the arch at any part by the tightening ſcrew at the back. When this index is to be moved any conſiderable quantity, the ſcrew muſt be releaſed, and, when the index is brought nearly to the diviſion required for the obſervation, the ſcrew at the back muſt be made tight; then, by turning the ſcrew *E*, called the *adjuſting ſcrew*, the index will be moved ſlowly along the arch, ſo that the obſervation may be made with the greater exactneſs.

The teleſcope *M*, which magnifies about four times, is uſed inſtead of a common ſight; the object being magnified a little, appears more diſtinct, and, by ſliding the tube that contains the eye glaſſes in the inſide of the other tube, the object is made to appear diſtinct to different eyes. The ſame teleſcope is applied both to the fore obſervation and to the back obſervation; when it is uſed for the fore obſervation, it is ſcrewed into the circular ring as is ſhewn fig. 2; and when uſed for the back obſervation, it is ſcrewed into the other circular ring at *f*.

The part that ſupports the teleſcope when uſed for the back obſervation is repreſented at fig. 3; the upper part is the circular ring into which the teleſcope is to be ſcrewed; *aa* are two pins that go into two holes in the frame of the inſtrument, to give the teleſcope its proper poſition; then, by ſcrewing up the part *g* againſt the back of the frame, the whole is made faſt to the inſtrument.

This part is ſo contrived that it may be removed from *f*, fig. 2, (where it is uſed for the back obſervation) and fixed at O, fig. 1, to be uſed in the adjuſtment of the back horizon-glaſs. The ſcrews *bb* go through the ring into which the teleſcope is ſcrewed, and draw this ring againſt two pins fixed to the under ring at the ſides *pp*.

By looſing one of the ſcrews, and tightening the other, the teleſcope may be adjuſted parallel to the plane of the inſtrument; the method of knowing when it is ſo will be deſcribed hereafter. By means of the ſcrew *r*, the teleſcope is moved nearer to, or farther from, the plane of the inſtrument, that it may be directed either to the ſilvered or to the unſilvered parts of the glaſſes. The part into which the teleſcope is ſcrewed for the fore obſervation has the ſame adjuſtments, but is fixed to the inſtrument.

The parts of the horizon-glaſſes next the plane of the inſtrument are ſilvered, and the part of the index-glaſs next the plane of the inſtrument is alſo ſilvered; but the extent of the ſilvered part of the index-glaſs exceeds the extent of the ſilvered parts of the horizon-glaſſes as much as is the diameter of the aperture of the object-glaſs of the teleſcope; the remaining part of the index-glaſs is made black at the back, that the light may be reflected from the outer ſurface only. By this method of ſilvering the glaſſes, the obſervation may be made *three* different ways, any of which may be uſed according to the difference of the brightneſs of the two objects whoſe angular diſtance is to be meaſured.

Firſt, if the object to be ſeen by reflection be obſcure, move the teleſcope as near as you can to the plane of the ſextant by turning the ſcrew *r*; more than one half of the aperture of the object-glaſs of the teleſcope will then be directed to the ſilvered part of the horizon-glaſs; and the image of the object will be ſeen in the ſilvered part of the horizon-glaſs reflected from the ſilvered part of the index-glaſs. *Secondly*, if the object be bright enough to be ſeen in the unſilvered part of the horizon-glaſs, move the teleſcope by turning the ſcrew *r*, till the whole aperture is directed to the unſilvered part of that glaſs, ſo as to be juſt clear of the ſilvered edge, and the image of the object will then be ſeen in the unſilvered part of the horizon-glaſs, but reflected from the ſilvered part of the index-glaſs. *Thirdly*, if the object be ſtill brighter, move the teleſcope as far from the plane of the ſextant as the ſcrew will admit, and the image of the object will then be ſeen in the unſilvered part of the horizon-glaſs, and alſo reflected from the unſilvered part of the index-glaſs.

The laſt of theſe three methods is much to be preferred to either of the former; for the object appears more diſtinct when reflected only from one ſurface of the index-glaſs than when reflected from both, and any errors that may ariſe from the two ſurfaces not being perfectly parallel will be entirely obviated: it may be added, that the appearance of the object, when darkened by this method, is much more agreeable than when it is darkened by interpoſing the darkening glaſſes.

The tube *R* is to be applied in the ſame manner as the teleſcope, to direct the ſight in a line parallel to the plane of the inſtrument, both in the fore and in the back obſervation. It may be uſed at ſea when the weather is rough, or for taking the angular diſtances of land objects; for which purpoſe it will be found more convenient than the teleſcope.

Fig. 4. is a frame that holds a magnifying-glaſs to aſſiſt the ſight in reading off the diviſions on the arch. The part *v* is put on to the edge of the arch, and may be ſlipped along it to bring the glaſs *s* over any part required.

Fig. 5. is another frame that holds a magnifying-glaſs to aſſiſt the ſight in making the line on the end of the index *PD*, to coincide with the lines *u* or *w* in adjuſting the back horizon-glaſs. The dove-tail part *y* (in fig. 5) being ſlipped on at *y* at the end of the index in fig. 1. and 2, the magnifying-glaſs will then be directly over the line.

Fig. 6. is a key to turn the ſcrew *n* to adjuſt the back horizon-glaſs into the perpendicular poſition; this key being put through the back part of the frame, the ſquare end goes into the inſide of the ſcrew *n*, which is alſo made ſquare to receive it.

Fig. 7. is a ſhade to be fixed with the ſcrew *x*, before the ſilvered part of the index-glaſs, to prevent a glare of light, when the obſervation is made from the unſilvered part of that glaſs.

The accuracy of the back obſervation very much depends on the adjuſtment of the index applied to the back horizon-glaſs; it is therefore neceſſary to have a method of moving that index with the greateſt exactneſs in making the adjuſtment; for this purpoſe the following is preferred, as being the moſt exact and convenient method: the piece of braſs at *z*, fig. 1. and 2. goes through the wooden frame, and is turned round by a lever at the back. This lever is moved by turning a circular piece, the edge of of which appears at *q*. The index *PD* has a pin fixed underneath, near the end; this pin fits into a notch made acroſs the circular piece of braſs at *z*, and near its circumference. When the pin is put into the notch, the finger ſcrew that draws the index down muſt be put through the frame of the ſextant, and ſcrewed into the index *nearly* tight; then, by turning the button *q*, the index will move ſlowly, and thus the lines may eaſily be made to coincide. When this is done very exactly, tighten the finger ſcrew underneath to make the index faſt, that it may not move either during the adjuſtment, or during the obſervation: the ſame method is uſed to procure an exact coincidence of the lines both at *u* and at *w*.

The reſt of the proceſs of making the adjuſtments of the horizon-glaſſes of the ſextant being the ſame as in the octant, already deſcribed in pages 10 and 18, it need only be obſerved, that the moon or any of the brighter ſtars may be uſed for that purpoſe, and the adjuſtment may be made with more eaſe, and perhaps with more exactneſs, by the moon or ſtars than by the ſun.

Some eminent obſervers think the method of finding the error of adjuſtment (commonly called the *index error*) and of allowing for it in the obſervation, is more to be depended on than making the adjuſtment;

ment; and they rather chuſe to make that allowance than to alter the adjuſtment of the inſtrument. Several methods have been uſed for this purpoſe, of which the following ſeems to be the beſt.

To find the error of adjuſtment, commonly called the index error.

TAKE the diameter of the ſun or moon by moving the index forward; and alſo take this diameter by moving the index backwards. If the numbers ſhewn on the arch be the ſame in both caſes, the glaſſes are then truly adjuſted. If the numbers be different, then half their difference is the index error. If the diameter taken in moving the index forward exceeds the diameter taken in moving the index backwards, then the half difference is to be ſubtracted; if the contrary, it is to be added. It muſt be obſerved, that in reading off the diviſions of the vernier when the index is moved backwards, that the complement of the numbers ſhewn on the vernier to 20, is to be taken, and not the numbers themſelves. Several obſervations of the ſun's diameter being made in this manner, and a mean of the whole being taken, the index error may be found by this method to a very great exactneſs.

The nearer the ſight is directed in a line parallel to the plane of the ſextant in making the obſervations,

tions, the more exact will thoſe obſervations be. For this reaſon there are two wires fixed parallel to each other, at the focus of the eye-glaſs, in the eye-tube of the teleſcope, by which the field of view is divided into three parts; when an obſervation is to be made, the wires muſt be ſet parallel to the plane of the inſtrument, by turning the eye-tube round, and the image of the object ſeen by reflection ſhould be brought into contact with the object ſeen by direct viſion between theſe wires, and as near to an imaginary line in the middle between them as may be.

If the teleſcope is not fixed parallel to the plane of the inſtrument, the middle between the wires will not be the proper place to bring the objects to, in making the obſervations, therefore the following directions are given for adjuſting the teleſcope.

To adjuſt the teleſcope parallel to the plane of the ſextant.

CHUSE any two diſtant objects, whoſe angular diſtance is not leſs than 90 degrees. The ſun and moon are the moſt proper objects to be uſed at ſea for this purpoſe. Bring their neareſt limbs into contact at the wire neareſt to the plane of the ſextant; then, by altering the poſition of the ſextant a little, bring them to the wire furtheſt from the plane of the ſextant. If their neareſt limbs be in contact as before, the teleſcope is properly adjuſted; but if the limbs of the ſun and moon lap over one another when they are brought to the wire furtheſt from the plane of the ſextant, it ſhews the object end of the teleſcope to be inclined *from* the plane of the ſextant. To rectify this, unſcrew the loweſt of the two ſcrews *b b* of the ring into which the teleſcope is ſcrewed, as ſhewn in fig. 3, and tighten the higheſt of thoſe ſcrews. If the neareſt limbs of the ſun and moon do not come in contact when they are brought to the wire furtheſt from the plane of the ſextant, it ſhews the object end of the teleſcope to be inclined *towards* the plane of the ſextant; in this caſe unſcrew the higheſt of the two ſcrews *b b*, and tighten the loweſt. By repeating this operation a few times, the teleſcope may be properly adjuſted. The ſame method of adjuſting the teleſcope is to be uſed both in the fore obſervation and in the back obſervation.

To take the altitude of the moon at ſea by the fore obſervation.

THE ſame method is to be uſed in taking the altitude of the moon as in taking the altitude of the ſun, only it muſt be obſerved that the enlightened edge, or that edge which is round and well defined, muſt be brought into contact with the horizon, whether it be the upper or the under edge *. The moon is generally bright enough to be ſeen by reflection from the unſilvered parts of the glaſſes; if not, the teleſcope muſt be moved nearer to the plane of the inſtrument.

Care muſt be taken that the wires in the teleſcope be turned exactly parallel to the plane of the ſextant; for then, by keeping them perpendicular, they may ſerve as a guide in the night-time for holding the ſextant in a vertical poſition; as that poſition cannot be ſo well determined by the ſweep of the ſextant in the night as it can be in the day time.

The obſerved altitude of the moon requires four different corrections before the true altitude of her center above the real horizon can be obtained.

FIRST CORRECTION. The ſemi-diameter. To be found page 7 of every month in the nautical almanac for every noon and midnight at Greenwich. If the lower limb was obſerved, *add* the ſemi-diameter thus found; if the upper limb was obſerved, *ſubtract* it.

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* If the teleſcope be of that kind that ſhews objects inverted, then the upper edge or limb of the moon will appear the lower, the left ſide will appear at the right, and the contrary.

Second Correcrion. The dip of the horizon. To be *ſubtracted.*

Third Correction. The refraction to be *ſubtracted.*

Fourth Correction. The moon's *parallax* in altitude. To be found from the requiſite tables to the nautical almanac, is to be *added.*

Theſe four corrections being applied to the obſerved altitude of the moon, the true altitude of her center above the real horizon will be obtained.

To take the altitude of the moon at ſea, by the back obſervation.

IN taking the altitude of the moon by the back obſervation the ſame methods are to be followed, and the ſame cautions are to be obſerved, as in the fore obſervation; it only need be noted, that the *firſt* and *ſecond* corrections muſt be applied the contrary way to what they are in the fore obſervation; but the *third* and *fourth* muſt be applied the ſame way.

To take the diſtance of the moon from the ſun by the fore obſervation, in order to determine the longitude at ſea.

IN the nautical almanac you may find the central diſtances of the ſun and moon calculated for every three hours at Greenwich, on ſuch days as this method is practicable. From the diſtances thus found, compute roughly the diſtance between their neareſt limbs at the time of obſervation, as directed in page 165 and 166 of the nautical almanac.

Set the index to the diſtance of the neareſt limbs of the ſun and moon ſo found. If the ſun be to the left hand of the moon, the ſextant muſt be held with the face downwards; but if the ſun be to the right hand of the moon, it muſt be held with the face upwards. Direct the teleſcope to the moon, and put the ſextant into ſuch a poſition, that if you look edgeways againſt it, it may ſeem to make a line paſſing through the ſun and moon; then, by giving the ſextant a ſweep, or ſwinging it round a line parallel to the line of ſight, the reflected image of the ſun will paſs by the moon, and ſo near that you cannot miſs ſeeing it. Their neareſt limbs muſt be brought into exact contact by moving the index with the adjuſting ſcrew *E*, ſo that giving the ſextant the motion round the line of ſight, the reflected image of the ſun in paſſing by the moon may juſt touch her neareſt limb, which is always round and well defined. The wires in the teleſcope muſt be turned parallel to the plane of the ſextant, and the contact muſt be made in the middle between them as before deſcribed. The obſervation being made with care according to the foregoing directions, the diviſions on the arch will ſhew the *apparent* diſtance of the neareſt limbs of the ſun and moon. This diſtance requires two corrections to obtain the *true* diſtance of their centers as ſeen from the center of the earth.

FIRST CORRECTION. The ſum of their ſemi-diameter. To be *added.*

The ſemi-diameter of the ſun for every ſixth day, and of the moon for every noon and midnight at Greenwich, may be found in the nautical almanac; from whence their ſemi-diameters at the time of obſervation are to be computed by the rule in page 152 of the requiſite tables to the nautical almanac. This correction gives the apparent diſtance of the centers of the ſun and moon.

SECOND CORRECTION. To clear the apparent diſtance of the effects of refraction and parallax. To make this correction, two ſets of tables, with directions how to uſe them, are to be found among the requiſite tables to the nautical almanac. This correction may be more eaſily made from a ſet of tables publiſhed by the board of longitude for that purpoſe.

Theſe two corrections being properly made to the apparent diſtance of the ſun and moon, the true diſtance of their centers, as ſeen from the center of the earth, will be obtained; and the time at the place of obſervation being known, the *longitude* of the place may be computed by the rules and tables belonging to the nautical almanac.

To take the diſtance of the moon from the ſun by the back obſervation, to determine the longitude at ſea.

THE ſame directions as before given for the fore obſervation muſt be followed in the back obſervation, excepting that the face of the ſextant in making theſe obſervations muſt be turned contrary to what was directed in the fore obſervation; and it muſt be obſerved, that the diviſions on the arch ſhew the complement of the angle obſerved to 180 degrees, and not the angle itſelf.

To take the diſtance of the moon from ſuch ſtars as are ſelected in the nautical almanac for finding the longitude at ſea.

THE diſtances of thoſe ſtars from the moon's center are alſo given in the nautical almanac for every three hours at Greenwich; from whence the diſtance from the enlightened limb of the moon may be computed as before. None of theſe diſtances exceed 120 degrees, therefore the fore obſervation only is to be uſed.

Set the index to the diſtance thus computed. If the ſtar be to the left hand of the moon, the ſextant muſt be held with its face upwards, and the contrary. The moon will generally be bright enough to be ſeen be reflection from the unſilvered parts of the glaſſes, and by two reflections will be ſufficiently darkened, ſo as not to hinder the ſtar from being ſeen when brought into contact with her. Direct the teleſcope to the ſtar, then put the ſextant into the proper plane as before, and giving it a ſweep round a line parallel to the line of ſight, the reflected image of the moon will paſs by the ſtar, and ſo near that you will ſee it in the field of the teleſcope. This will be a proof that the ſight is directed to the right ſtar. By turning

ing the adjuſting ſcrew, the enlightened limb of the moon (whether eaſt or weſt) may be brought into contact with the ſtar, and by giving the ſextant a ſweep round a line parallel to the line of ſight, the enlightened limb of the moon may be made juſt to touch the ſtar as ſhe paſſes by it, and that in the middle between the two wires in the teleſcope.

The index will then ſhew the *apparent* diſtance of the ſtar from the enlightened limb of the moon, to which apply the two following corrections.

First Correction. The ſemi-diameter of the moon. This may be found in the nautical almanac for every noon and midnight at Greenwich, from whence her ſemi-diameter at the time of obſervation is to be computed by the rule in page 162 of the tables. If the obſerved or enlightened limb of the moon be the neareſt to the ſtar, the ſemi-diameter thus found is to be *added*; if the enlightened limb be the furtheſt from the ſtar, then the ſemi-diameter is to be *ſubtracted*. This correction gives the apparent diſtance of the moon's center from the ſtar.

Second Correction. To clear the apparent diſtance of the effects of refraction and parallax. This correction muſt be made from the tables, *&c.* as before directed for the ſun and moon.

Theſe corrections being properly made, the true diſtance of the moon's center from the ſtar, as ſeen from the center of the earth, will be obtained; and the time at the place of obſervation being known, the longitude of the place may be computed from the rules and tables belonging to the nautical almanac.

The ſtar to be uſed is always one of the brighteſt, and its poſition is always nearly in a line perpendicular to the line of the moon's horns, or which is the ſame thing, in the line of the moon's ſhorteſt axis produced. If you are not certain which is the right ſtar, having ſet the index to the diſtance of the ſtar from the moon, as found from the nautical almanac, hold the ſextant as near as you can judge, ſo that its plane (ſeen edgeways) may coincide with the line of the moon's ſhorter axis, and moving it in that plane, ſeek the reflected image of the moon through the teleſcope; then give a ſweep with the ſextant, ſo as to turn it round the incident ray, that is round a line paſſing from the moon to the inſtrument. By this ſweep the moon may be kept in the field of the teleſcope, and the ſtar will be ſeen to paſs by her.

A readineſs in making theſe obſervations may certainly be acquired by practice; this has been fully proved by the great uſe that has of late years been made of this method to determine the longitude at ſea, and the many excellent improvements lately made in it, both in theory and practice, by the Aſtronomer Royal, leave no room to doubt but it will ſoon be brought into general uſe.

This inſtrument may be uſed at land to take the double altitude of the ſun or ſtars, by reflection from water or quick-ſilver, in order to determine the latitude of any place; and alſo to obſerve correſponding altitudes of the ſun to examine the going of a clock, by which means the time will be exactly known, and the longitude of the place may be determined by the eclipſes of Jupiter's ſatellites.

To obſerve the altitude of the ſun at land, by reflection from water.

THE trough that contains the water ſhould be five or ſix inches long and three or four inches wide; muſt be laid on the ground, or on ſomething that is firm, and muſt be ſheltered from the action of the wind by a machine in the form of the ſlant roof of a houſe; this may be a wooden frame, with pieces of glaſs fixed into the ſides. The pieces of glaſs uſed for this purpoſe ſhould be truly flat, and the two ſurfaces of each glaſs ſhould be parallel to each other. This machine muſt be laid over the water-trough, but not to touch it, otherwiſe it may occaſion the water to ſhake.

Being thus prepared, move backwards till you ſee the reflected image of the ſun in the water; if this image be very bright, turn one or more of the darkening glaſſes at *H* behind the horizon glaſs. Now, holding the ſextant in a vertical plane, direct the ſight to the ſun's image in the water, then move the index till you ſee the other image, reflected from the mirrors come *down* to the ſun's image ſeen in the water, ſo as to touch but not to paſs it; then bring their edges into contact in the middle between the wires of the teleſcope, as before directed.

The diviſions on the arch will ſhow the double altitude; to this you muſt add or ſubtract the index error, if any, according to which way it is; to half this ſum or difference add the ſun's ſemidiameter, and ſubtract the correction for refraction; you will then have the true altitude of the ſun's center above the real horizon.

If the altitude be more than 60 degrees the back obſervation muſt be uſed. By moving the index forward (that is, towards you, in this caſe) the image of the ſun reflected from the mirrors muſt be brought *up* to the ſun's image ſeen in the water, ſo as to touch but not to paſs it; then the edges being brought into contact in the middle between the wires in the teleſcope, the diviſions on the arch will ſhow the ſupplement of the double altitude to 180 degrees. From half the double altitude thus found, the ſun's ſemidiameter and the correction for refraction being both *ſubtracted*, the true altitude of the ſun's center above the real horizon will be obtained.

The altitude of a ſtar is taken in the ſame manner as the altitude of the ſun, except that quickſilver muſt be uſed inſtead of water; for but few of the ſtars are bright enough to be ſeen reflected from water. The double altitude of the ſtar muſt be corrected for the index error, if any, and then halved; the half being corrected for refraction only, gives the true altitude of the ſtar above the real horizon.

To obſerve correſponding altitudes of the ſun.

FOR theſe obſervations it is neceſſary to be provided with a clock. The moſt proper times for making the obſervations, is when the ſun is near the *prime vertical*, that is, the eaſt or weſt points of the compaſs. About this time in the forenoon obſerve ſeveral double altitudes of the ſun, write down the degrees and minutes ſhown on the arch, and alſo the exact time ſhown by the clock at each obſervation, and let the different obſervations made in the forenoon be wrote one below the other, in the order they are made.

In the afternoon ſet the index to the ſame degree and minute as the laſt morning obſervation. Note very exactly the time ſhown by the clock, when the ſun is obſerved to come down to the ſame altitude, and write the time down on the right hand of the laſt morning obſervation. In the ſame manner proceed to find the time by the clock of all the altitudes correſponding to thoſe taken in the morning, and write down each one, oppoſite to that morning one, to which it correſponds.

Take now the firſt pair of the correſponding altitudes, add them together, and to half their ſum add ſix hours; this being corrected for the change of the ſun's declination * between the morning and afternoon obſervations, you will have the time of ſolar noon derived from this pair of obſervations. Do the ſame for each pair, and taking the mean of the times thus found from each pair, you will have the exact time ſhown by the clock at ſolar noon. From the equation of time in the ſecond page of every month

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* This correction may be eaſily computed for any latitude from a table given for that purpoſe in the nautical almanac for 1769.

in the nautical almanac you will find the difference between ſolar and mean time, which being added to or ſubtracted from the ſolar time, according as it is ſooner or later, gives the true time of ſolar noon, that is, the time that would be ſhewn by a clock that went perfectly right; compare this with the time actually ſhown by your clock, and its error will be given.

With a teleſcope that magnifies about 40 or 50 times, the eclipſes of Jupiter's ſatellites may be ſeen at land, and the time at the place of obſervation being found as before, the longitude may be determined by the rules given every year in the nautical almanac for that purpoſe.

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THE END.

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